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REPORT

REDUCTION OF CROSS-COLOUR EFFECTS IN PAL (SYSTEM I) COLOUR TELEVISION BY THE USE OF LOW-PASS AND NOTCH FILTERS: subjective tests

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Summary

Luminance components of a PAL colour television signal that lie within the frequency band occupied by the chrominance subcarrier and its sidebands are liable to produce cross-colour effects on the displayed colour picture.

To mitigate these effects the response/frequency characteristic of the luminance channel of a four-tube colour television camera was modified by including, in turn, a wide-notch filter, a narrow-notch filter (both centred on colour subcarrier frequency) and a 3·6 MHz low-pass filter. This Report presents the results of subjective tests of the effects of these filters on the resolution, cross-colour and colour spreading of a PAL (System I) colour picture; the tests were carried out for two values of decoder chrominance-channel bandwidth. The resolution of the compatible monochrome picture was also examined.

The results indicate that the inclusion of a 3·6 MHz low-pass filter in the camera luminance channel provides a substantial reduction of cross-colour with little loss of resolution. It was also judged that the narrower bandwidth chrominance decoder provided a useful reduction in cross-colour with little apparent loss of chrominance resolution.

Issued under the authority of

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1. Introduction

In a colour-television system using an in-band chrominance subcarrier, cross-colour is the unwanted effect caused by components of the luminance signal entering the chrominance demodulators. These components may be due to a repeated pattern whose frequency (or one or more of its harmonics) lies within the chrominance passband, or to a single transition or group of transitions. Movement of objects in the scene that produce these components results in changes to the spectrum of the luminance signal with consequent changes in the cross-colour effects, and can often render the cross-colour more conspicuous.

Cross-colour effects may be reduced in several ways, the simplest being:–

(i) removal from the luminance signal, before it is combined with the chrominance to produce the PAL signal, of components at frequencies near to that of the chrominance subcarrier. The response of the requisite filter may be a notch, centred on the subcarrier frequency, or it may have a low-pass characteristic. Either type will have a beneficial effect on the signal-to-noise ratio, as well as on cross-colour, but at the expense of degrading the resolution of both the colour picture and the compatible monochrome picture.

(ii) reducing the bandwidth of the chrominance channel of the decoder. This, however, has an adverse effect on the horizontal resolution of the chrominance signal, producing an effect on the colour picture referred to in this Report as 'colour spreading'.

This Report describes a series of subjective tests designed to assess the effects of these measures.

2. The equipment used

For most of the tests the signal source was a four-tube colour camera, the channel associated with the luminance tube being wide-band (approximately 5·5 MHz) and those fed by the colouring tubes relatively narrow band (approximately 1·6 MHz). Thus the cross-colour produced by components of the coded signal within the chrominance band was due to the luminance channel of the camera, with virtually no contribution from the colouring channels. Aperture correction was set so that the overall response of the luminance channel (including the camera-tube) was increased by 3 dB at 5 MHz.

Various filters could be included in the camera luminance channel, before gamma correction. These were

(i) a narrow notch centred on subcarrier frequency, with a bandwidth of ±300 kHz at −3 dB.

(ii) a wider notch centred on subcarrier frequency, with a a bandwidth of ±750 kHz at −3 dB.

(iii) a low-pass filter with an attenuation of 3 dB at 3·6 MHz.

The response/frequency characteristics of the luminance filters are shown in Fig. 1 and the 2T-pulse responses in Fig. 2.

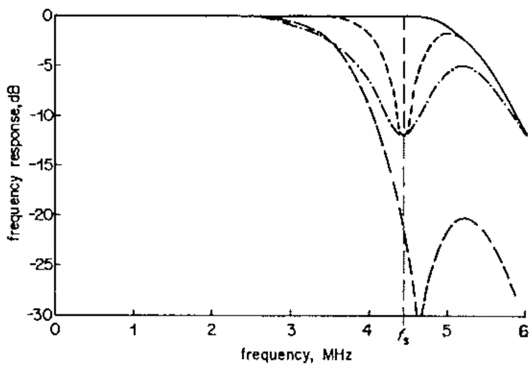


Fig. 1 - Frequency response characteristics of luminance channel

———— without added filtering
– – – – – with narrow notch, ±300 kHz at −3 dB
—·—·— with wide notch, ±750 kHz at −3 dB
— — — with low-pass filter, 3·6 MHz at −3 dB

Two PAL decoders were used, which differed with regard to the bandwidth of their chrominance channels. They are designated Decoder A and Decoder B and their chrominance-channel response curves are shown in Fig. 3. The decoder luminance-channel notches[1] were nominally identical and their characteristic is also shown in Fig. 3. The narrower-band decoder (Decoder B) is the more representative of current domestic receivers.

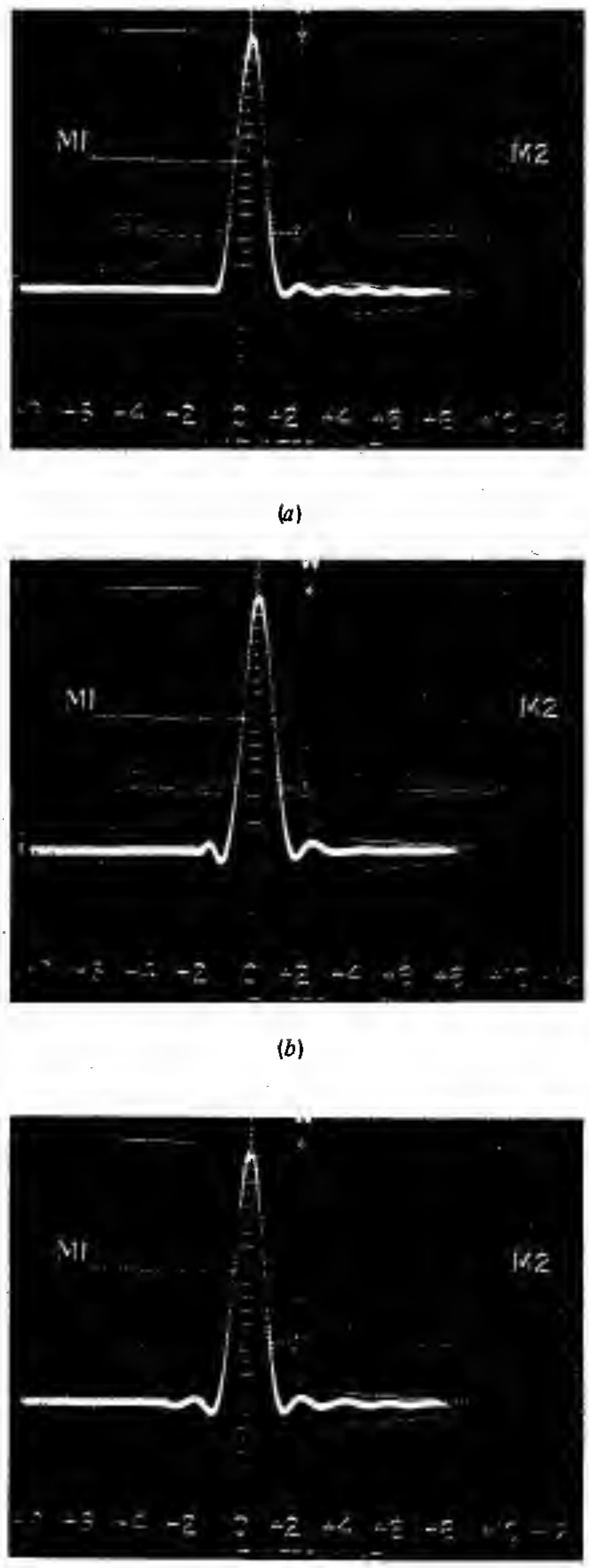
3. Test conditions

3.1. The studio set

The camera was used in a small studio, the set being arranged to include:–

(i) Printed lettering (labels on boxes, bottles and newsprint)

(ii) Boxes with clearly-defined areas of bright colour



(*a*)

(*b*)

(*c*)

Fig. 2 - 2T-pulse responses of luminance-channel filters

(*a*) Narrow notch	$k_{2T} = <1\%$	$k_{p/b} = <1\%$
(*b*) Wide notch	$k_{2T} = 1\%$	$k_{p/b} = 1½\%$
(*c*) Low-pass filter	$k_{2T} = 1\%$	$k_{p/b} = 1\%$

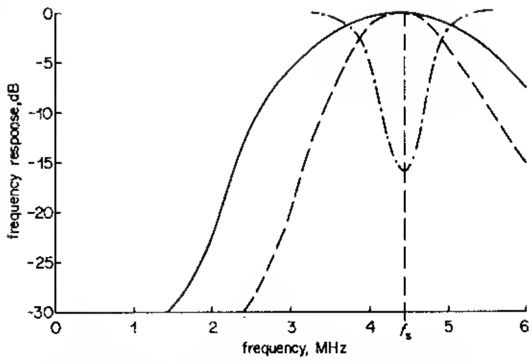


Fig. 3 - Characteristics of PAL decoders

——— Decoder A, chrominance channel
— — — Decoder B, chrominance channel
—·—·— Both decoders, luminance channel

(iii) Fabrics with striped or check patterns, either stationary or placed on a turntable which rotated twice per minute.

(iv) Small objects producing specular reflections.

The fine detail in the scene included items producing luminance components at all frequencies that could cause cross-colour. The striped fabrics, in particular produced very marked cross-colour effects when they were on the rotating turntable.

3.2. Viewing conditions

In the viewing room a monochrome monitor, fed with composite video signal, was placed between two colour monitors each showing the same picture, either in its RGB (uncoded) form or in the decoded form as derived from either of the decoders. The viewers were placed at a distance of approximately six times picture height from the monitors, and were asked to look at the monochrome picture and the nearer colour picture, ignoring the other (nominally identical) colour picture. Standard EBU viewing conditions were used (peak white 75 cd/m^2, ambient lighting 7·5 cd/m^2 and picture contrast approximately 100/1).

3.3. The viewers

There were four viewing groups each having six observers. Twelve observers were engineers, and twelve non-technical staff.

3.4. The assessments

3.4.1. Tests using camera pictures

The viewing groups were asked to assess

(i) the sharpness of the monochrome picture

(ii) the sharpness of the colour picture

(iii) the low-frequency colour spreading in the colour picture

(iv) cross-colour in the colour picture.

For the first and second assessments the six-point quality scale was used, while for the third and fourth the six-point impairment scale was used. These scales are defined in Section 3.5.

3.4.2. Tests using material replayed by a video tape recorder

A video tape recording of signals derived using no additional luminance filtering was also used in the tests; the recording included pictures containing little fine detail, but some very well-defined areas of strong colour. This was replayed, using each decoder in turn, and repeated with the decoders switched in the reverse order. The viewers were asked to assess the colour spreading and the cross-colour.

3.5. The assessment scales

The assessments were recorded using the following scales:

The six-point quality scale

1. Excellent
2. Good
3. Fairly good
4. Rather poor
5. Poor
6. Very poor

The six point impairment scale

1. Imperceptible
2. Just perceptible
3. Perceptible but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

4. Results of the subjective tests

4.1. Camera pictures

The mean values (ρ), standard deviation (σ) and the standard error of the means ($\sigma/\sqrt{n}$) of the subjective gradings recorded in the camera tests were:—

	No filter			Narrow notch			Wide notch			Low-pass filter		
	ρ	σ	$\frac{\sigma}{\sqrt{n}}$	ρ	σ	$\frac{\sigma}{\sqrt{n}}$	ρ	σ	$\frac{\sigma}{\sqrt{n}}$	ρ	σ	$\frac{\sigma}{\sqrt{n}}$
Sharpness of monochrome picture	1·8	0·9	0·09	2·0	0·9	0·13	2·7	0·8	0·12	2·7	0·8	0·12
Sharpness of colour picture												
Decoder A (wide-band)	2·5	0·9	0·13	2·7	0·9	0·18	2·8	1·0	0·15	2·8	0·8	0·12
Decoder B (narrow-band)	3·0	1·0	0·15	3·1	0·9	0·16	3·0	1·0	0·15	3·1	0·9	0·13

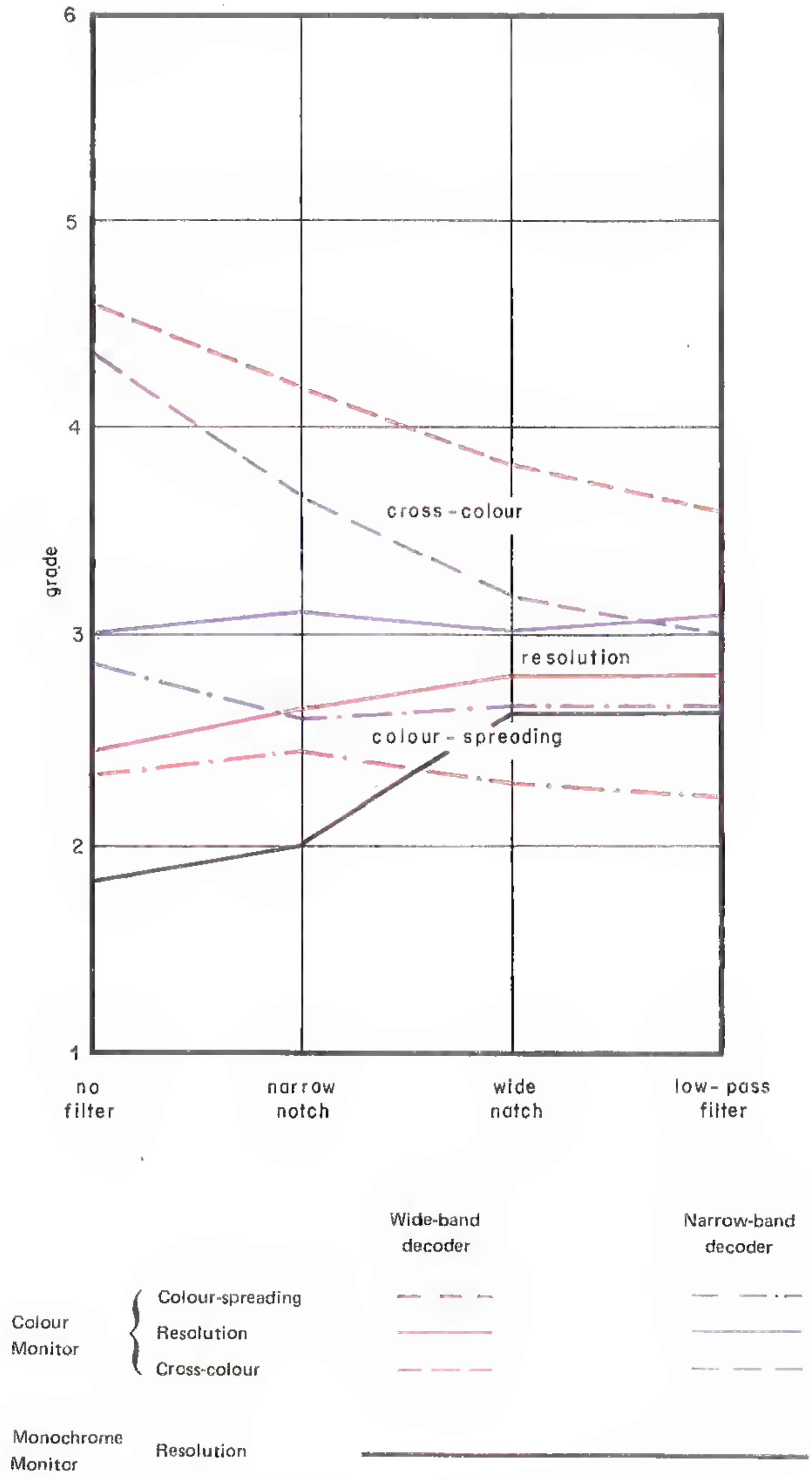
(As a comparison, the RGB (uncoded) picture, with no filter, was graded 1·6, with standard deviation 0·6, and standard error of mean 0·08)

	No filter			Narrow notch			Wide notch			Low-pass filter		
Colour spreading												
Decoder A (wide-band)	2·4	0·9	0·14	2·5	0·9	0·12	2·3	0·8	0·12	2·3	0·8	0·12
Decoder B (narrow-band)	2·9	1·0	0·15	2·6	1·0	0·15	2·7	0·9	0·13	2·7	0·9	0·14

(As a comparison, the RGB (uncoded) picture, with no filter, was graded 1·3, with standard deviation 0·8, and standard error of mean 0·12)

	No filter			Narrow notch			Wide notch			Low-pass filter		
Cross-colour												
Decoder A (wide-band)	4·6	0·9	0·12	4·2	1·1	0·16	3·9	0·8	0·12	3·6	0·8	0·12
Decoder B (narrow-band)	4·4	0·9	0·12	3·7	1·0	0·15	3·2	0·7	0·09	3·0	0·7	0·11

These results are shown diagrammatically in Fig. 4



Resolution assessed on quality scale
Cross-colour and Colour-spreading assessed on impairment scale

Fig. 4 - Results of subjective tests using the camera

4.2. Pictures from video tape recorder

The mean values (ρ) and standard deviation (σ) of the subjective gradings recorded in the tests using video tape were

Colour spreading

	ρ	σ	$\frac{\sigma}{\sqrt{n}}$
Decoder A	2·5	0·6	0·09
Decoder B	3·2	1·0	0·15

Cross colour

	ρ	σ	$\frac{\sigma}{\sqrt{n}}$
Decoder A	2·1	0·8	0·12
Decoder B	2·2	0·9	0·14

5. Discussion of the results

5.1. Picture sharpness, assessed on the six-point quality scale

5.1.1. The monochrome picture

Insertion of the narrow and wide notch filters caused correspondingly worse degradation of the picture sharpness (Grades 1·8 and 2·7). The picture sharpness with the wide notch and the low-pass filter were, however, graded equal although subsidiary checks using a test card showed the expected differences.

5.1.2. The colour picture

The overall sharpness of the colour picture produced by the narrower-band decoder (Decoder 8) was not judged to vary significantly with the type of luminance filter used. The picture sharpnesses with the wide notch and the low-pass filter were graded equal, although (as for the monochrome picture) differences were noted using test cards.

In the case of the wider-band decoder (Decoder A), the introduction of successively increased filtering into the luminance channel caused a just noticeable reduction in picture sharpness, but again the difference between the wide notch and the low-pass filter was not detected.

In the monochrome and both the colour cases the above were 'worst case' tests since many domestic receivers will attenuate luminance signals in the region of 5·0 MHz, to a significant extent.

5.2. Colour spreading, assessed on the six-point impairment scale

As expected, it was found that the changes of camera luminance-filter response had little effect on the assessment of colour spreading.

When assessing camera pictures, the subjective grades obtained using the narrower-band decoder were, on average, 0·4 of a grade worse than for the wider-band decoder, whose pictures were approximately one grade worse than the uncoded RGB pictures. The assessments using the videotape recording showed a difference of 0·7 of a grade between the results for the two decoders.

5.3. Cross-colour, assessed on the six-point impairment scale

The results with camera pictures showed a steady reduction in cross-colour as the camera luminance response was successively restricted. The narrower-band decoder (Decoder B) was judged to produce less cross-colour than the wider-band decoder (Decoder A) and also to benefit more from the use of a camera luminance filter. This is an expected result, since in the case of the narrower-band decoder the luminance filter in the camera removes a greater proportion of the luminance components that fall within the selected chrominance band. Tests with videotape pictures were less critical and did not show any significant difference between the decoders.

6. Alternative methods of reducing cross-colour

The tests described in this Report involved modifications to the camera and decoder which were easily instrumented. It is probable that comparable improvements in cross-colour could be obtained with less degradation of picture sharpness if more complicated techniques were used. For example, advantage could be taken of the characteristics of the frequency spectrum of the decoded colour signal by using comb filters[2] in the camera (and possibly in the receiver decoder) to divide the shared part of the spectrum into narrow bands separately containing luminance and chrominance information. A study has been made of the problems involved and a Report is being written.[3]

7. Conclusions

The narrower-band decoder (which is believed to correspond fairly closely with modern receiver practice) gives better protection than the wider-band decoder against cross-colour caused by luminance components spaced from the chrominance subcarrier by 1 MHz or more. This advantage is gained at the cost of a slight increase of colour spreading and some loss of subjective picture sharpness, but on balance the narrower-band decoder is preferred.

Restriction of the camera luminance-channel bandwidth improves the cross-colour at the expense of a small reduction in picture sharpness of both colour and monochrome pictures.

Consideration of the subjective assessments alone would lead to the conclusions that the low-pass filter is preferable, since it results in marginally less cross-colour than the wide notch. The difference is 0·2 of a grade in the case of the narrower-band decoder.

The use of a notch in the coder, however, is more in line with the provisions made in the System I Specification.[4] In the future, comb filtering in the coder may prove to be a better solution than either a notch or a low-pass filter; further, comb filters in receivers might become practicable, offering the prospect of an additional improvement.

8. References

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